

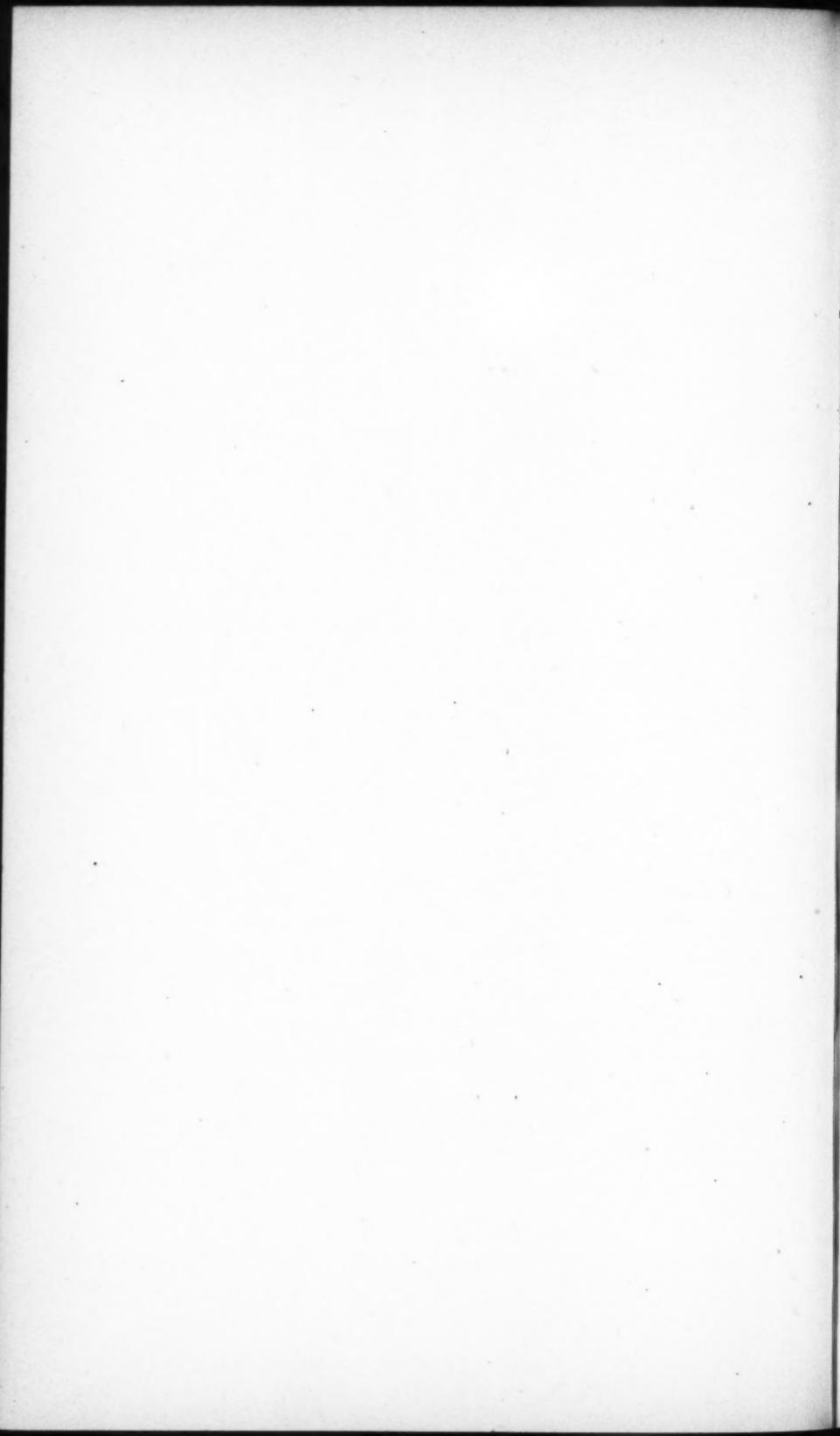
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CONTRIBUTIONS FROM THE ZOOLOGICAL LABORATORY OF THE
MUSEUM OF COMPARATIVE ZOOLOGY AT HARVARD COLLEGE,
E. L. MARK, DIRECTOR.—No. 190.

*MATURATION STAGES IN THE SPERMATOGENESIS
OF VESPA MACULATA LINN.*

BY E. L. MARK AND MANTON COPELAND.



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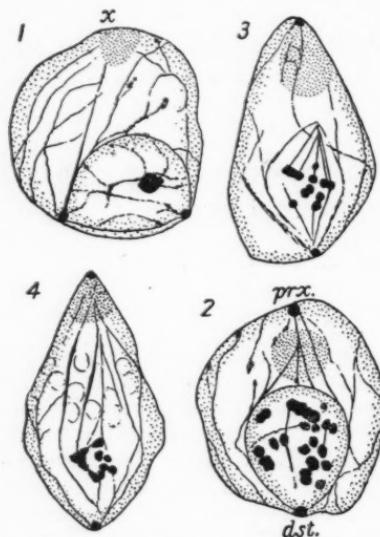
In a brief account of spermatogenesis in the honey bee, published four years ago, Meves (:03) showed that, contrary to the condition thus far observed in the animal kingdom generally, the maturation divisions of the primary spermatocytes resulted in the production of two "Richtungskörper" and a single functional cell, instead of four functional spermatozoa. The first of these two bodies was composed exclusively of cytoplasm; the second, however, was nucleated. Our observations on the germinal cells of the honey bee published last year (Mark and Copeland, :06) confirmed in a general way those of Meves, differing from his, however, in numerous details.

Meves states in a very few words in the paper cited that in the spermatogenesis of *Vespa germanica* the first maturation division results, as in the honey bee, in the formation of a non-nucleated bud of cytoplasm, but that the second gives rise to two cells of equal size, both of which are metamorphosed into spermatozoa.

Having been able to collect, prepare, and examine the male germinal cells of *Vespa maculata Linn.*, we will set forth briefly in this paper some of our observations.

At the end of the growth period following the last spermatogonial division, the cells (compare Figure 1) closely resemble those of the honey bee. The nucleus is relatively large, and the chromatin is for the most part aggregated into a single, somewhat irregularly shaped body. Lying against the cell membrane are the remnants of the interzonal filaments of the preceding cell division, which have become metamorphosed into a rather homogeneous mass, to which we have given the name interzonal body (Figure 1, *x*).

As the spermatocyte enters the prophase of the first maturation division the centrosome, lying in contact with the cell membrane, divides, and the two daughter centrosomes move apart (Figure 1) until they arrive at opposite poles of the cell (Figure 2).



FIGURES 1-4. Primary spermatocytes. $\times 2800$.

FIGURE 1. The two centrosomes moving apart; *x*, interzonal body.

FIGURE 2. Centrosomes at opposite poles of cell; nucleus showing chromosomes; *prx.*, proximal centrosome; *dst.*, distal centrosome.

FIGURE 3. First spindle figure with intranuclear spindle fibres.

FIGURE 4. Interzonal body at proximal pole, immediately before its abstraction; spindle figure disappearing, and extranuclear fibres prominent.

Although the centrosomes during their migration seem to influence to some degree the form of the cell, this modification in outline is not so prominent as in the honey bee. The nucleus continues to lie close to that one of the centrosomes which in the cells of the honey bee we have designated as the distal centrosome (Figure 2, *dst.*).

The stages immediately following this correspond strikingly to those of the honey bee. The chromatin, after passing through a spireme condition, gives rise to chromosomes which lie scattered irregularly through the nucleus (Figure 2). We have not as yet succeeded in determining the exact number of the chromosomes, but believe that it is not less than sixteen. The nucleus now elongates, finally becoming more or less spindle shaped, but apparently fails to reach the proximal pole of the cell. Intranuclear spindle fibres staining in iron haematoxylin have meanwhile made their appearance, extending from the chromosomes first to the distal centrosome, and later in the opposite direction, to a region near the proximal end of the nucleus, it being now difficult to determine the exact extent of the nuclear membrane. Thus the proximal ends of the spindle fibres often appear to converge to a point at some distance from the corresponding centrosome (Figure

3); unlike the corresponding stage in the honey bee, there seems to be no evidence that these fibres connect with the proximal centrosome; however, numerous *extranuclear* fibres extend from the distal centrosome in the direction of the proximal one.

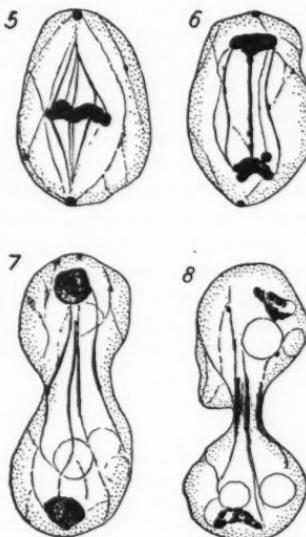
At this stage the interzonal body already lies near the proximal centrosome.

The proximal end of the cell now elongates (Figure 4), and there is formed a small bud of cytoplasm containing the interzonal body and the proximal centrosome. This bud remains for a time connected with the cell by a neck-like process of cytoplasm, through which may be traced extranuclear fibres. This connecting process of cytoplasm becomes more and more attenuated until a complete detachment of the protoplasmic globule is effected.

This "Richtungskörper" consists chiefly of the interzonal body, but in most cases the interzonal body is surrounded by more of the unmodified cell protoplasm than exists in the corresponding globule of the honey bee. Like the latter, it contains no chromatin.

We have good evidence to show that the proximal centrosome divides, and that the two daughter centrosomes, in some cases, at least, move apart around the periphery of the globule. This migration may begin before the protoplasmic bud has become completely separated from the parent cell.

During the period of the abstraction of the interzonal body and accompanying cytoplasm, which closely resembles that of the honey bee, the development of the spindle figure is arrested, as in the bee, not being carried beyond the beginning of the metaphase. It is diffi-



FIGURES 5-8. Spermatocytes after the abstraction of the interzonal body (i.e., secondary spermatocytes) $\times 2800$.

FIGURE 5. Spindle figure of second maturation division in the beginning of the metaphase.

FIGURE 6. Anaphase of second maturation division.

FIGURE 7. Early telophase.

FIGURE 8. Late telophase. Spermatocyte nearly divided into two spermatids.

cult to determine the fate of the chromosomes and spindle fibres at this time. The former appear to be aggregated to a greater or less extent, and their individuality seems thereby to be obscured.

After the formation of the non-nucleated "Richtungskörper" the chromatin is found to occupy the equator of the spindle, where it has regained the appearance of more or less distinct chromosomes. Thus is formed a fairly characteristic spindle figure in the metaphase (Figure 5). Division of the chromosomes now takes place, and the daughter chromosomes migrate toward the poles of the spindle, leaving stretched between them interzonal filaments (Figure 6). As the cell enters on the telophase it elongates, and a constriction is then formed at the equator (Figure 7). The constricting process is continued until the daughter cells remain connected to each other by only an attenuated neck of cytoplasm, through which can be traced the interzonal filaments. There result two spermatids, both apparently destined to become functional spermatozoa, for these cells, unlike the corresponding cells of the honey bee, are equal in size; they are immediately metamorphosed into spermatozoa.

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